PROGRAMMED INSTRUCTION in the INDUSTRIAL SITUATION

By

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1. Introduction

THE changing technology of our times is generating pressing needs for a speedy, economical and effective solution of the problems of education and training. There is a shortage of skilled manpower, not only in South Africa, but throughout the world. In addition to the fact that every new worker must be trained to use complex tools skilfully, there is also an ever-increasing demand for better training facilities to teach experienced workers the modern procedures that are constantly developing. Therefore it has become necessary for the skilled worker to remain a trainee in order to satisfy the needs of the changing occupational society. Stolurow([43]) describes this change in the following words: "Now, however, occupational change is a fact of life; trades are quickly modified, and almost overnight new processes and new products make acquired skills obsolete".

Out of this pressing need a new method has been developed in the form of programmed instruction—an exciting new technique in the hands of the teacher and the industrial trainer. Pressey([30]) was the first to foresee this coming revolution in education, but he had to wait from the 1920's to the late 1950's for his dreams to materialise through the work of Skinner([39]), who succeeded in placing this new teaching technique, which has much in common with the ancient Socratic Dialogue([9]), on the sound empirical basis of modern learning theory. Programmed instruction was soon adopted and modified by Crowder([11]) with his *Intrinsic Programming*, Gilbert([24]) with his *Mathematical Design and Effective Lessons*, and Evans, Glaser and Homme([15]) with their Ruleg System. The many books published on this subject in the last three years, of which the works of Galanter([16]), Margulies and Eigen([28]), Mager([25]), Stolurow([43]), Dolmatch([13]) and Lysaught([24]) are only a few, prove that writers as well as publishers are very active in this field. A recent publication by Ross([32]) describes forty different teaching machines already on the market.

Perhaps the main reason why this method of teaching could not materialise before the 1950's, is the fact that means of duplicating programmes and producing teaching aids were not yet available to make text books and instructional devices accessible to every learner in every classroom or training establishment. For many years there has been no major change in teaching techniques, but the time has come for the effective application of learning theory and modern research tools to teaching and training practice. Furthermore, programmed instruction is a powerful tool in the hands of the experimental psychologist that can lead the way to a better understanding of human learning and the evaluation of the learning theories. The need for schematic learning theory has long been felt([38]) and programmed instruction can bring us to new insights into the learning process([1]). Bartmann([2]) of Germany has very recently (1963) pointed out how better understanding between association and field theories could develop through programmed instruction. The results of an objective, empirical evaluation of the learning theories could then be used to improve methods of teaching and training. In their book on *Training in Business Industry*, McGehee and Thayer([27]) emphasise the industrial applications of learning theory. Therefore combined and co-operative research by educationists and industrialists in this connection is an absolute necessity. In South Africa we do not have the field for applying or the financial means to justify duplication of basic research, and industrialists as well as educationists can only benefit by exchanging views in a conference such as this.

2. Programmed instruction in industrial teaching and training

Programmed instruction has definite applications in the industrial training situation. This technique is a method of self-instruction, and can therefore be of considerable value in adult teaching. Publications by Lysaught([23]) and Dolmatch([13]) indicate various possibilities in this connection.

The value of programmed instruction for correspondence colleges and self-instruction at post-matriculation level is obvious. It would therefore not be too bold to declare that if programmed instruction is worth the trouble and cost in the school system, then it is even more so in the industrial situation.

Dolmatch([12]) describes programmed instruction as a significant new tool for the training director. He suggests that it might be best to avoid the phrase "teaching machines" altogether, because some teachers see themselves becoming obsolete because of this new-fangled device, and some training directors are secretly beginning to wonder whether they too might not become casualties of automation. But they have nothing to worry about. They will not be replaced any more than the accountant was by the installation of data-processing machines. Instructional devices will accelerate learning just as data processing speeded data collection, and should upgrade the job of the training man just as automation upgraded the financial and information-gathering functions of the accountant. There are good and bad programmes, just as there are good and bad teachers. The effective programmes will do the job well, but the poorest ones are probably worse than nothing at all. The field of programmed instruction is still in its infancy, and the chances are that many of the first programmes will not come up to standard. This, however, should not deter the training man from searching out good programmes and benefiting from them—for the evaluation of a programme, trainee performance must be the sole criterion.

Dolmatch([12]) points out that in terms of market strategy it would seem logical for companies involved in programmed training to emphasise the programme rather than the device carrying it. This can be compared with the razor and the blade. Only good blades shave well; likewise only good programmes teach effectively. Experimentation now going on indicates that there will soon be new instructional devices that are less expensive than some now being sold. Everything will depend on the market and the productivity of the firms and institutions engaged in the development of this new field.

Programming has many advantages in the industrial situation, according to Dolmatch([12]). In the first place, the time spent in conventional training costs a great deal of money. Indications are that programmed instruction speeds learning([20]), and therefore it could be used as a cost-cutting tool of great significance. In the second place, the consistency of a programme solves many problems. Even the best human instructor has his subjective moods, and therefore conventional methods cannot give every group of trainees the same, effective course. The exacting demands of a programmed course will also point out weak spots in training that previously could not be identified. Thirdly, since programmed instruction is a solo affair, the troublesome organising to get a class together at a suitable time and place becomes unnecessary—each learner gets his training at his own pace and during the period that suits him best. Christian([8]) points out that the decentralised training resulting from programmed courses can get a company out of the travel and hotel business. In the fourth place, programmed instruction provides a great deal of motivation by setting up a situation in which the student is virtually compelled to learn. Only by proving that he has mastered the material can he proceed to the next frame. Finally, the application of programmed instruction gives the training director a new role in industry. Relieved of the tasks of instructing, attendance-checking and test-administering, he can spend more time searching for the correlations between training and performance, and the application of theoretical findings in the field of learning psychology to reconstruct and improve his courses.

According to Lysaught([22]), the training director should use the following points to determine the subjects to be programmed:

(*a*) Known difficulty with the present training approach.
(*b*) Number of students to be trained.
(*c*) Permanence of the subject-matter.
(*d*) Estimated time for development.

Bruce points out that Eastman Kodak was compelled to use a programmed logarithm course as a supplement to regular training. In order to understand sensitometry([44]), the student must first understand logarithms. Before they could present the course in sensitometry, they had to bring all the individuals up to the same level in logarithms. This was done by programmed self-instruction. Rust([33]) emphasises a transfer approach to programmed training in the industrial situation, because it is the environment in which the trainee is employed that should dictate the kind of training he is to have in order to develop the desired job behaviour. Most employers consider the ability to function in a job more important than the ability to talk about the job, and it is to this end that any form of instruction is given and that decisions to programme training experiences must be made.

3. Programmed instruction in military teaching and training

The application of the principles of programmed instruction to military programmes is described in detail by Margulies and Eigen[28], who point out that the United States military organisations have contributed a great deal to the field of programmed instruction. The work of military personnel in this field is of particular interest to those concerned with industrial training problems and educational programming, because teaching in the military situation encompasses both of these areas. Many of the existing programmes, machines and simulators have been developed under U.S. Military auspices. The reports of Besnard[3,4], Briggs[6], Silverman [35,36], Bishop and Regan of the U.S. Naval Training Device Centre[5], Eckstrand of the Air Force Systems Command[14], and Hosmer and Nolan of the Lackland Air Force Base[20] can probably be regarded as representative of the large volume of work undertaken in this area.

Eckstrand[14] points out that the major military training problems are cost of training, individual differences, quality control, shortage of instructors, and trainee motivation. The cost of training is high because a large number of personnel given initial specialised training are available for only a single enlistment that could be as short as three years, and even those who remain in the service require frequent retraining with new weapons and procedures. Individual differences and the ability to profit from training have always been a problem in any form of teaching, and self-instructional devices seem ideally suited to solve this problem in the case of adult training in the Armed Forces. Military training also requires rigid control of the products of training. Specified performance with high reliability must be produced if a military operational capability is to be assured. Programmed instruction, with its definition of criterion performance, and its empirical evaluation and improvement of programmes, could hold the solution to this problem. The shortage of highly-trained and experienced instructors is one of the most serious problems of military training, and if only part of this job could be done by automated teaching devices, it would be of great value. Although there is not much firm data regarding the motivational characteristics of instructional devices, the fact that it does not allow the student to proceed before having mastered the given information, and that immediate knowledge of results is a basic principle of the system, could solve the problem of trainee motivation.

In the South African military training situation, a few problems can be isolated that could at least be partly solved by the application of the principles of programmed instruction. The first is the shortage of trained manpower. In modern warfare it is absolutely essential that every soldier should be a trained man, capable of operating complicated devices. Therefore the findings of modern learning psychologists should be applied to military training with the ultimate aim of training every individual to the utmost of his capabilities. In this regard, co-ordinated research should be the objective.

The second problem confronting the South African military trainer is the fact that, in the case of a state of emergency, there will not be time to train instructors to train the men from all walks of life. Libraries of programmed basic subjects can then be used in self-instructional courses to bring all trainees up to the same level as soon as possible, so that they can benefit from further courses that could even be led by instructors who do not know the subject, providing the course is programmed. Programmed, self-instructional courses could also be of great value for the training-in-combat of men who receive new devices in entrenched positions from where they cannot be recalled for a training course.

To mention a specific example, modern warfare has become dependent on the use and repair of electronic devices. Every soldier should be capable of repairing the instrument that is at his disposal. Therefore, a course of basic electronics has become an absolute necessity in all army training. A teaching machine such as the Italian Electronic Teaching Desk could be used with programmes composed according to the principles of programmed instruction to teach every man the basic principles of electronics and to take him to the necessary level of performance within a given unit of time. In this regard, the experience of Briggs[6] and Geer[17] could be a helpful guide.

4. Programming experience of the National Institute for Personnel Research

The National Institute for Personnel Research of the C.S.I.R. in Johannesburg is at present programming a course in Introductory Algebra. We decided to use this subject as a pilot study after coming to the conclusion that all advanced technical programming in the industrial field presupposes a basic knowledge of the first principles of algebra and graphs. To bring all trainees to the same level of performance, a course in Introductory Algebra is an absolute necessity. This course can also be used as a basic library to which students could be referred when they make certain mistakes in advanced programmes. Because there is no such course available applicable to South African conditions, we decided to construct one.

With only a few American publications on the art of programming at our disposal, and without a single overseas programme as example, we started programming by trial-and-error with members of our Institute as subjects. The first lesson consisted of 75 frames presented in textbook form according to Skinnerian principles, but it was found to be too long to be completed by all subjects in the period of twenty minutes that we chose as the optimum period of effective, concentrated learning. Therefore, we divided it into two lessons of 36 frames each, which is at present the standard length of our lessons of which a total of 18 are at present being tested. Each lesson is followed by a diagnostic test consisting of 12 frames, so that our total programming up to date produced a series of lessons and tests consisting of 864 frames.

After each lesson, the subject is given a test in lesson form, but without answers, to complete before he can proceed. This test fulfils a dual purpose. In the first place, it assures that a cheating pupil will be identified and advised to repeat the lesson before being allowed to proceed with the following lesson, and in the second place, it serves as a diagnostic test to indicate where a subject with previous mathematical experience should start doing the lessons. The series of tests, which can be done independently, makes this a modified linear programme.

The special features of our programme can be summarised as follows:

(*a*) It consists of self-contained lessons, each explaining one defined principle, so that a prospective student can be referred to a specific lesson for definite information. The criterion performance for each lesson is defined and tested in the diagnostic test to prove to the learner that he has learnt something, and to assure that he understands the basic principle contained in that lesson before he is allowed to continue.

(*b*) The tests are in the form of lessons without answers, so that a student who is capable of doing the tests, can save time by skipping lessons explaining principles that he already understands.

(*c*) Each lesson can be used as a separate unit, because the lessons are not bound together in book form. Therefore one programme can be used to teach many students who are not doing the same lesson.

This programme was devised as a sound basis for advanced technical programming in the industrial field, but it could also be of value in the school situation. The ten year-old son of an American member of our personnel has completed the first eight lessons successfully. Although he is only in standard three and has no previous mathematical experience, he scored 12 out of 13 in the final test for the series with no other practice or exercise than doing the 384 frames of the series. A ten year-old girl, in standard four, obtained the same score.

This programme has been tested and is now being retested with a total of 28 members of our personnel and their relatives as subjects, and the preliminary report on a pilot study scheduled to last a year, will be given in part 5 of this paper. Mr. L. A. Gouws, of the University College of the North, is at present investigating the possibility of applying our programme, or a modified version, to Bantu school children in the Northern Transvaal in the course of work for his D.Phil.(Psychology) thesis.

The National Institute for Personnel Research is planning further basic research in the field of programmed instruction. One of the first aspects that we would like to investigate is the teaching of basic reading and writing to adult illiterates by means of programmed instruction. We are at present studying the possibilities in this regard and are developing a card sorting system for the teaching of reading, while a tracing system seems to be the most applicable to the teaching of writing. The possible use of colour is contemplated([45]), and the use of a branching box([31]) should also be tested. Unfortunately, this investigation is at present being delayed by the lack of suitable subjects. If possible, we would like to combine this investigation with basic research on certain aspects of teaching the spoken language by language laboratory([19]), knowing that there are special problems in programming language instruction for teaching machines([40]). Because there is no experimental evidence to support Skinner's contention that self-pacing is more effective than machine-pacing([36]), we would also like to investigate the relevance of machine-pacing for the design of future instructional devices.

5. A preliminary report on a pilot study in programmed instruction

We read about programmed instruction, and decided to test our skill writing a programme in Introductory Algebra, for reasons already mentioned. The dual purpose was in the first place, to find out whether this new method really teaches, and in the second place, to develop a programme that functions effectively. Members of our personnel and their relatives are used as subjects in this pilot study that was started during January, and is scheduled to continue for at least the rest of this year. It is not a controlled experiment, and the subjects come from all walks of life, including whites as well as non-whites, and adults as well as children. Some of them have a mathematical background, while others have never done mathematics before. A full report on the construction and applicability of this course cannot be available before next year, but because certain trends can be observed, suggesting fields for controlled experimentation, some indication of results already obtained will now be given.

TABLE I

Results from Lesson 1 and Lesson 1a (Reconstructed)

	LESSON 1				LESSON 1a			
	Time Lesson	*Errors Lesson*	*Errors Test*	*Time Test*	*Time Lesson*	*Errors Lesson*	*Errors Test*	*Time Test*
Mean	49	8	1	7	15	1	0	4
Range	47	19	3	3	31	4	0	5
Sample Size	8	8	8	8	21	21	21	21
	72 frames		12 frames		36 frames		12 frames	

The results indicate that empirical information can be used to improve programmed lessons.

TABLE II

Results for First Group of Subjects

Lessons 1 to 7

Subject	*Total Time*	*Time Lessons*	*Errors Lessons*	*Errors Tests*	*Time Tests*	*Final Test Errors*	*Final Test Time*
P1	232	180	9	0	52	2	15
P2	229	183	28	3	46	0	12
P3	211	168	8	3	43	0	15
P4	177	140	6	1	37	1	11
P5	167	132	5	0	35	1	10
P6	236	187	71	11	49	1	12
P7	338	268	18	4	70	0	16
P8	116	93	0	3	34	1	9
Mean	213	169	18	3	46	1	13
Range	222	175	71	11	36	2	7
Sample Size	8	8	8	8	8	8	8
Frames ..	384	288		96		13	

The results indicate greater differences in time than in final performance.

TABLE III
Results for First Group of Subjects
Lessons 8 to 13

Subject	*Total Time*	*Time Lessons*	*Errors Lessons*	*Errors Tests*	*Time Tests*	*Final Test* *Errors*	*Final Test* *Time*
P1	234	171	1	1	63	1	18
P2	223	165	6	1	58	0	13
P3	203	148	6	2	55	1	12
P4	180	133	2	4	47	2	6
P5	182	135	2	0	47	1	11
P6	262	186	5	7	76	2	15
P7	386	303	16	2	83	1	18
P8	133	94	1	1	39	0	10
Mean	225	167	5	2	59	1	13
Range	253	209	15	7	44	2	12
Sample Size	8	8	8	8	8	8	8
Frames	384	288		96		15	

In this case the final test was delayed for two weeks.

TABLE IV
Results for Second Group of Subjects
Lessons 1 to 7

Subject	*Total Time*	*Time Lessons*	*Errors Lessons*	*Errors Tests*	*Time Tests*	*Final Test* *Errors*	*Final Test* *Time*
A1	127	102	2	2	25	0	5
A2	110	95	0	5	31	1	4
A3	187	146	2	1	41	0	8
A4	296	215	10	3	81	0	20
C1	240	182	18	3	48	1	11
C2	181	157	12	2	44	1	10
D6	167	128	22	0	39	0	5
Mean	187	146	9	2	44	0·4	9
Range	186	120	22	5	56	1	16
Sample Size	7	7	7	7	7	7	7
Frames	384	288		96		13	

The results indicate greater differences in time than in final performance.

TABLE V
Two Subjects Doing Tests Without Lessons

Subject	*Total Time*	*Errors Tests*	*Time Tests*	*Final Test* *Errors*	*Final Test* *Time*
T1	27	8	27	0	5
T2	37	4	37	0	4
Mean	32	6	32	0	4·5
Range	10	4	10	0	1
Sample Size ..	2	2	2	2	2

The results indicate that subjects with previous mathematical experience can use the tests without the lessons.

6. Conclusion

I would like to conclude this paper by stating that we are optimistic about the future of programmed instruction in the industrial situation. It is a new technique that has come to stay, and a powerful instrument in the hands of the training director, providing that he selects the correct programmes and realises that programmed instruction is an empirical enterprise, based on a sound knowledge of psychological learning theory. If interest at the present rate continues, a wide variety of programmed materials will soon be available. Universities and research centres could produce more definite information on human learning, and industrial organisations could undertake the development of self-instructional courses to fit unique training needs. Lysaught([22]) is correct in stating that time spent in exploring the industrial applications of programmed instruction is well spent. We have also found such learning to be effective and economical. It can give us new insight into adult learning, and can provide us with new opportunities to improve industrial training.

Much has been said and written about the possible effects of the prolonged use of instructional devices on future generations. We agree with Ofiesh([29]) when he writes that automated teaching will not dehumanise man. It is poor teachers and instructors who have hidden behind routine drill that have led to much learning frustration in the past. Programmed instruction will give the teacher or instructor time to attend to individual needs of learners, and to improve his own methods. A new and objective method for the evaluation of learning is experienced by the pupil can only improve present instructional techniques.

The twentieth century has confronted man with another problem: That of training and teaching more men faster and better. The solution calls for the combined effort of educationists, industrialists, publishers, distributors and research workers. Experimentation on a provincial or local basis will not suffice; co-ordinated research is indispensible for the effective improvement of teaching and training in South Africa.

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